READING
WROUGHT IRON PIPE

Structural Differences in Wrought Iron & Steel

BULLETIN
No. 2

READING IRON COMPANY
Reading, Pennsylvania

STRUCTURAL DIFFERENCES IN WROUGHT IRON AND STEEL

Wrought *Iron* Pipe vs. Wrought Pipe

In 1887, the development of the Bessemer process of making steel opened up a new and cheap method for manufacturing welded pipe from a grade of soft steel. In order to compete with wrought iron pipe, which has been universally used since about 1812, manufacturers of steel pipe began designating their product as "Wrought Pipe." Although steel rightfully found its place in certain fields, time and actual service more and more displayed the inferiority of this new product for making welded pipe, where resistance to corrosion and the terrific vibratory, bending and torsional stresses must be considered. The misleading term "Wrought Pipe," however, has been insinuated into the trade customs of those engaged in the sale of steel pipe with the result that there exists today a confusion between the terms "wrought pipe" and wrought *iron* pipe.

The Term Wrought Pipe Unjustified

It is very apparent that neither the manufacturer of wrought iron pipe nor the manufacturers of steel pipe have the right to assume names in defiance of common usage. The term "wrought pipe" has never been recognized by the engineering and architectural professions and not even by the manufacturers of steel pipe themselves in all their advertising literature dealing with the relative merits of wrought iron and steel pipe.

The American Society for Testing Materials, the highest authority on specifications in this country, uses the terms:

(a) Welded steel pipe
(b) Welded wrought iron pipe

and these terms are closely adhered to in prevailing engineering and architectural practice.

The term "wrought pipe" sounds so much like wrought *iron* pipe that it has led to the careless use of the latter term to designate steel pipe, with the result that the wrought iron pipe manufacturers are deprived of this name to which they, alone, are entitled, since wrought iron is the only real name for pipe made from puddled pig iron that is recognized by the intelligent buying public.

The wrought iron pipe manufacturers brought this matter to the attention of the National Pipe and Supplies Association and asked them to adopt a trade custom that would distinguish between welded wrought iron pipe and welded steel pipe in conformance with the terms of the American Society for Testing Materials and the best engineering and architectural practice.

The Executive Committee of this Association, at its recent meeting held in New York, recognizing the merits of the wrought iron pipe manufacturers' contention, passed the following resolution:

"Whereas, the distributors of Pipe for many years used terms to designate the various types and makes of Pipe that have not been truly descriptive of same, and

"Whereas, it is the desire of this Association to co-operate in every way with the manufacturers in the development of trade practices and customs of accepted merit, and which will be fair and intelligible to the manufacturer, distributor and public alike,

"It Is Hereby Resolved by the officers and members of the Executive Committee and Advisory Board of The National Pipe and Supplies Association, in their Fall meeting, held in New York City, on Thursday, November 11th, that it is their judgment that the terms employed by the American Society for Testing Materials in differentiating between Iron and Steel Pipe, viz:

(a) Welded Wrought Iron Pipe
(b) Welded Steel Pipe

should be accepted and adhered to by the distributors of both Iron and Steel Pipe, this being in the interest of the manufacturers of the Pipe, those who distribute it and those who use it, each being entitled to know clearly and without doubt the make and quality of the Pipe involved in the transaction."

It is the purpose of this bulletin to show in the following pages the actual difference in composition and physical structure between Reading Wrought Iron Pipe and initially cheaper but ultimately far more expensive steel pipe.

In any discussion involving the relative merits of wrought iron and steel pipe, the structural differences of the two metals must be used as a basis for such discussion. For the purpose of showing this structural difference, several photo-micrographs are reproduced.

Steel Structure

Summed up briefly, the structure of steel as shown by these photo-micrographs consists entirely of a solid, uninterrupted mass of metallic grains composed of grains of ferrite (carbonless iron) and pearlite (iron containing carbon). The ferrite are the light grains and the pearlite are the dark ones.

The metallic portion of wrought iron consists

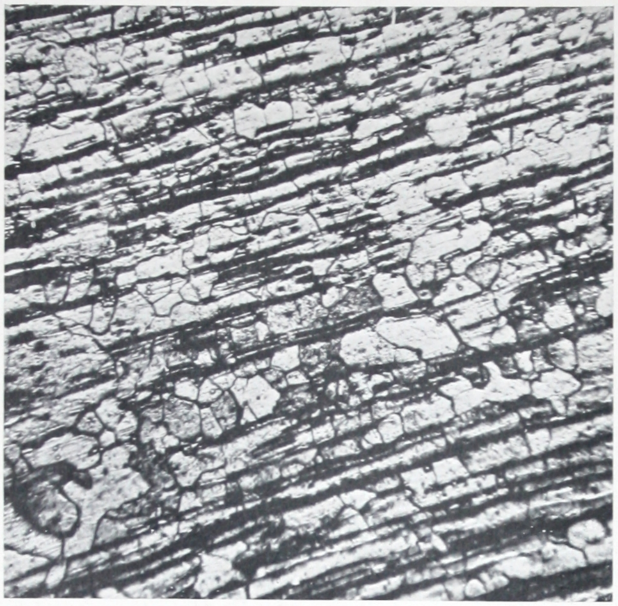


Fig. 1. Photo-micrograph of a longitudinal section of Reading Wrought Iron magnified 100 diameters.

Wrought Iron Structure

entirely of grains of ferrite of much greater purity than the ferrite in steel (owing to the absence of manganese—a known accelerator of corrosion), and in comparison with steel is conspicuous by the absence of pearlite. The metallic portion of wrought iron, however, not only assumes a different appearance from steel because the grains consist of but one constituent (ferrite), but also because of the 1.5 per cent to 2 per cent of slag associated with it. The continuity of these grains is almost entirely destroyed, due to the slag being drawn into fibres by rolling, which, in turn, divide the grains into clusters, as shown in photo-micrograph Fig. 1.

Fig. 2. Photo-micrograph of a longitudinal section of Reading Wrought Iron magnified 50 diameters.

Fibrous Structure of Wrought Iron

In describing the structures of the two metals, the term "metallic" has been used in place of "ferrous," and it is also quite true that this metallic portion of wrought iron, like steel, consists of small grains and may therefore be described as being crystalline. But as stated above, the continuity of these grains is almost entirely destroyed by the slag being drawn into fibres by rolling, which divides the grains into clusters. Therefore, it is rather inconsistent to deny that these fibres, distributed as they actually occur from 1-500 to 1-1000 of an inch apart throughout the metallic portion of the metal (Figs. 2 and 3), should not impart at least some of their own characteristics to wrought iron and make of it a composite mass having a truly fibrous structure as a whole. A moment's consideration of the above will clearly show that the application of the term "fibrous" to wrought iron is neither mythical nor imaginary, but an indisputable fact.

Fig. 3. Photo-micrograph of a transverse section of Reading Wrought Iron magnified 50 diameters.

Strength of Wrought Iron

Wrought iron has an ultimate strength of approximately 50,000 pounds per square inch, and an elongation of 25 per cent. And since it has been clearly shown for many years that wrought iron possessing such strength more than meets the most severe requirements of service where corrosion is the principal factor, there can be no logical reason

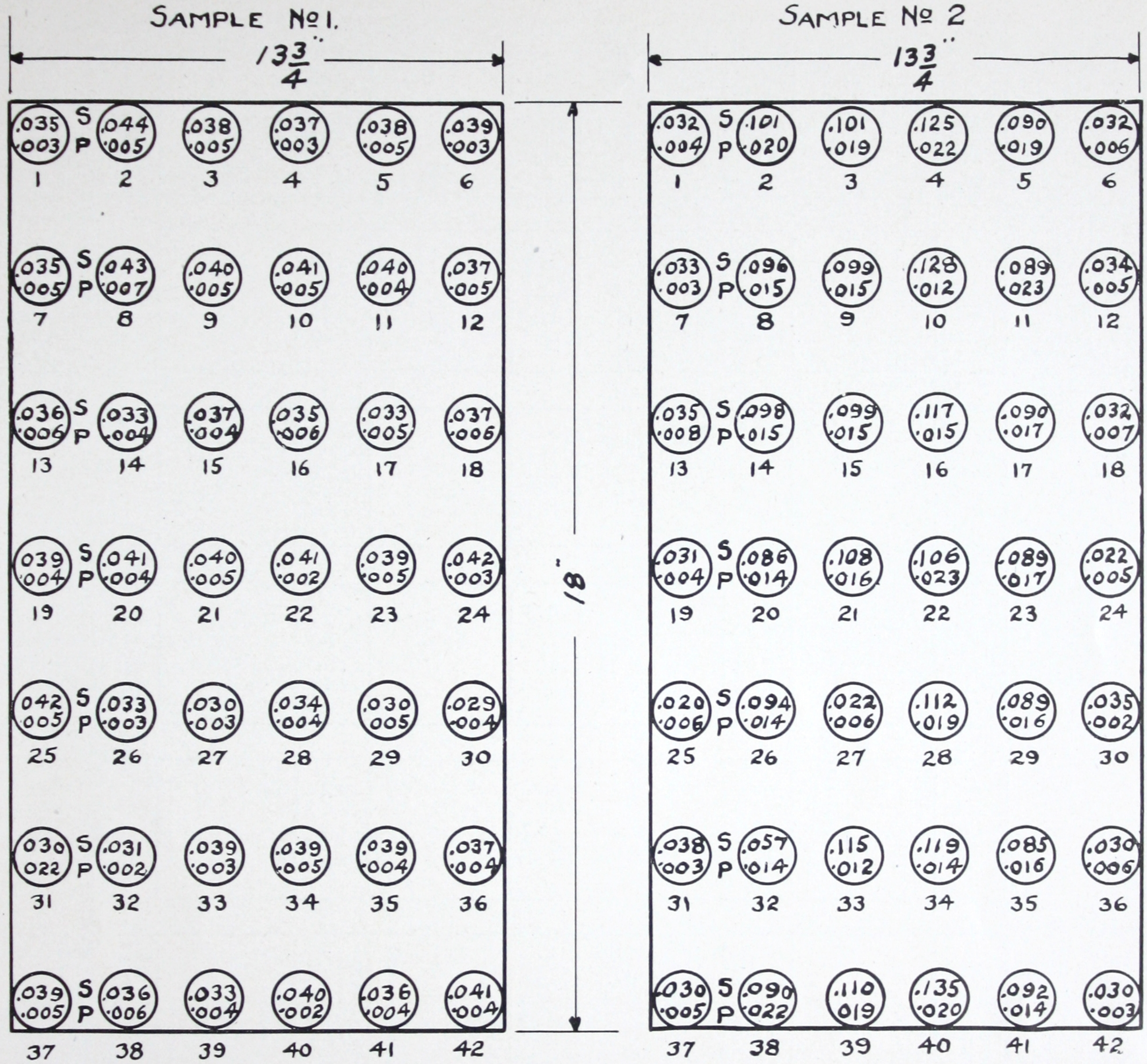


FIG. 4. Two samples of steel skelp from the same heat of steel, showing the variation in the percentage of sulphur and phosphorus. Note the tendency to segregate even in the same sheet.

for using a material for pipe such as steel on the basis of excess strength, at the sacrifice of the more vital properties relating to corrosion.

Wrought Iron's Ability to Withstand Fatigue

There is another property possessed by wrought iron which makes it particularly useful for pipe and superior to steel for the same purpose. This property may be described as its resistance to fatigue, due to shocks and alternating stresses. This quality in wrought iron is due to its fibrous structure, which, because of its fibres of slag, as previously explained, distribute the effect of such stress over a larger area of the metal instead of concentrating it in one small area, as in the case of steel. Consequently the course of fracture through wrought iron is not only more circuitous (see Figs. 2 and 3), but its progress is greatly delayed as the result. Wrought iron is therefore particularly useful in Oil Country and Railroad Service, as well as under conditions of expansion and contraction.

Homogeneity of Wrought Iron

Steel has frequently been described as homogeneous, and wrought iron as heterogeneous, and in doing so it is evident that reference is made to wrought iron's composite structure. Since the slag, however, is associated with the metallic portion of wrought iron in a purely mechanical form, and in such a manner as to protect this metallic portion from corrosion, it is evident that a compli-

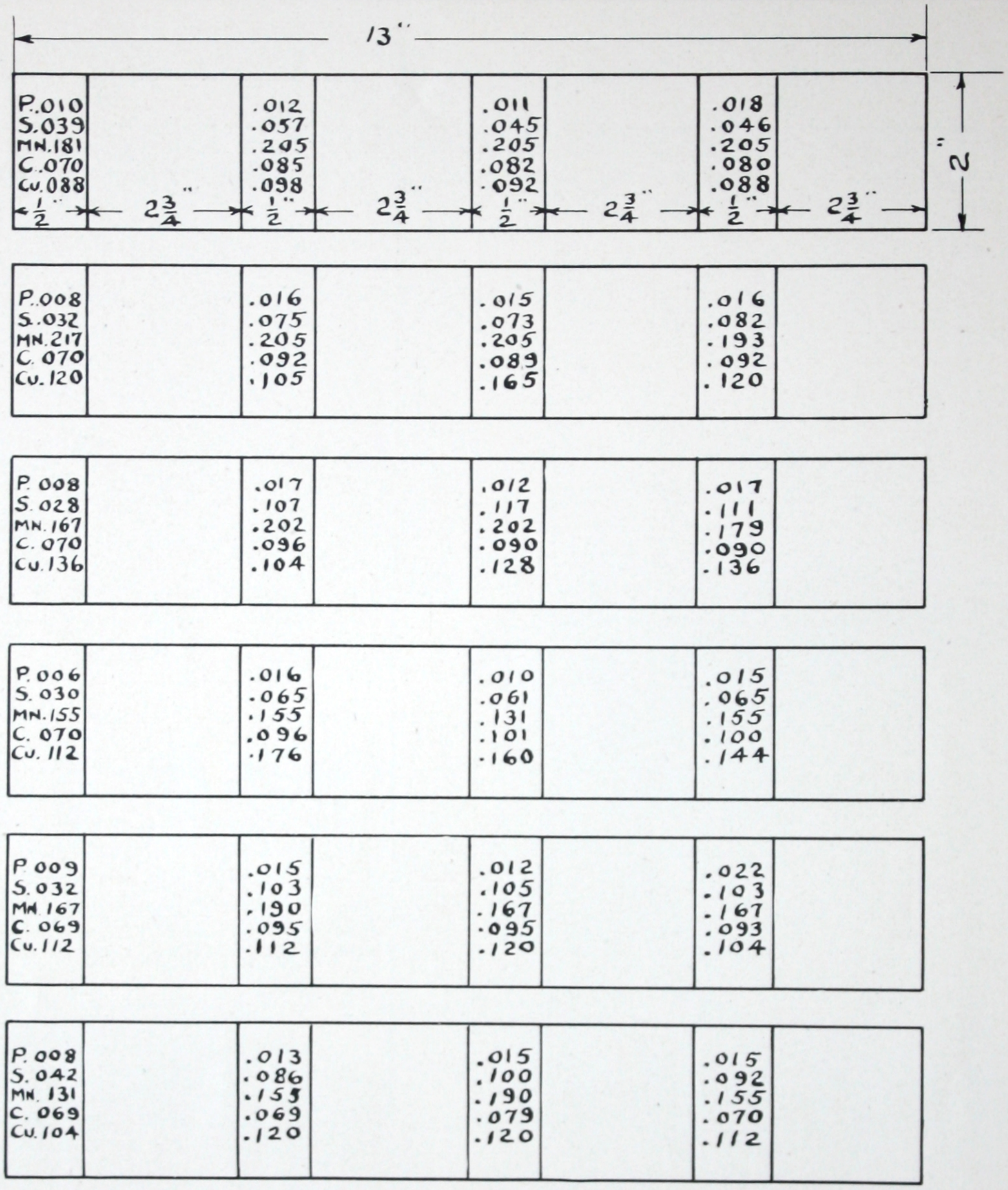


FIG. 5. Six samples of copper-bearing steel skelp 13 inches wide from the same heat of steel, showing variation in the percentage of phosphorus, sulphur, manganese, carbon and copper. Note the tendency to segregate even in the same sheet.

ment is conferred upon wrought iron in describing it as heterogeneous.

By homogeneity in metals is meant uniformity, sameness, or an absence of segregation within the metallic matrix or portion of the metal. Since the slag is mechanically associated with the metallic portion of wrought iron, and serves to protect this portion of the iron from influences of corrosion, it is apparent that the only part of wrought iron which should be considered on the basis of homogeneity would be the metallic portion itself. As the absence of any tendency to segregate in wrought iron is accepted by all metallurgists, the position of wrought iron is unique, not only as to its composite structure, but also because of the great homogeneity of its metallic structure.

Absence of Segregation in Wrought Iron

This homogeneity in the metallic portion of wrought iron is due to its method of manufacture, which permits of the most careful observation and control during the entire process. Furthermore, the metal is continuously worked during the process of puddling and particularly while it is solidifying from the molten to the solid state, thus preventing any tendency toward segregation of its component parts.

The liquid steel, after tapping from the furnace, is poured into ingot moulds, and is therein allowed to cool undisturbed from the liquid to the solid state. Due to slow cooling, there is a strong tendency on the part of the mass to reject its impurities, such as Carbon, Sulphur and Manganese, in unequal proportions toward the center or more liquid portion of the mass. This condition is quite common to all grades of steel in the course of their manufacture—pipe and boiler tube steel being no exception to the rule. This action is known as *segregation*, and will always exist as long as steel is manufactured in this present manner.

Segregation in Steel

Prof. Bradley Stoughton, in his article "Corrosion of Iron and Steel," in July, 1911, issue of the "Engineering Magazine," states:

> "It is generally admitted that segregated steel will rust much faster than the same metal in which the impurities are evenly distributed. The segregation of impurities arises during the solidification of molten masses, and is always present to some extent in Bessemer and Open Hearth Steel. It is practically unknown in Wrought Iron, because this solidifies in the furnace, and is constantly agitated meanwhile."

Examples of Segregation in Steel

Figures 4 and 5 show typical cases of segregation in steel skelp used in the manufacture of pipe and boiler tubes. These samples were selected at random from two different heats of steel. Samples Nos. 1 and 2 of Fig. 4 show the degree of segregation in the heat itself, while Sample No. 2 shows the degree of segregation even in the same piece of skelp. Fig. 5 also shows the degree of segregation both in the heat itself and in the skelp rolled from it. Visual evidence of the character of segregation within steel is further shown by Figs. 6–8, inclusive. These photo-micrographs were all made from a section cut from the same piece of steel pipe. The average analysis of borings

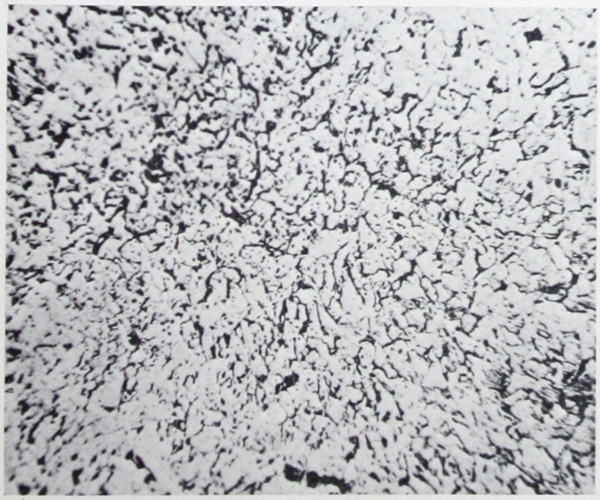


Fig. 6. Photo-micrograph of steel section magnified 100 diameters, showing low carbon structure in steel.

Fig. 7. Photo-micrograph of steel magnified 100 diameters taken from the same length of pipe as Fig. 6. The section to the left of the white line represents the badly segregated high carbon area, while the section to the right shows good steel.

from this length of pipe showed .12 carbon. The photo-micrographs, however, show carbon varying from approximately .09 to .40 carbon in spots within the same piece of steel pipe. Fig. 8 showing the greatest and Fig. 6 showing the least amount of carbon.

However, in spite of such evidence of heterogeneity in steel, which is acknowledged and admitted by all persons familiar with the manufacture of steel, some manufacturers of steel pipe persist in calling their product homogeneous and wrought iron heterogeneous.

Effects of Segregation

It is well known that segregated steel corrodes very rapidly. Yet few people realize that this lack of homogeneity caused by segregation is largely responsible for the irregularity noted in steel pipe, and particularly for the reason that various lengths of steel pipe under identical conditions of service in the same installation show such a variation in their resistance to corrosion. Recognition of this fact, together with the knowledge of the utter impossibility of ever being able to eliminate segregation in steel, has led the exponents of steel pipe to attack the homogeneity of wrought iron on the basis of its composite structure instead of the metallic portion of its structure, and in this manner minimize the effect of the slag, which is

FIG. 8. Photo-micrograph of steel magnified 50 diameters, the lower magnification being used to include more of the structure in the negative. This piece of steel was taken from the same length of pipe as Figs. 6 and 7. Section below the white line is badly segregated with carbon running from .19 to .40. Section above white line runs from .08 to .12 carbon.

responsible for the heterogeneous character of wrought iron as a whole, and thus create the erroneous impression that slag is a foreign substance of no value to the homogeneous base metal with which it is associated.

Advantages and Distribution of Slag in Wrought Iron

In wrought iron the presence of slag—a basic silicate of protoxide of iron—is not due to an accident, nor is it in any sense a foreign substance. On the contrary, it represents a very highly desirable and integral part of wrought iron because of the remarkable protection which it affords this material against corrosion. Several hundred thousand slag fibres are distributed over one square inch of metal section, so that the composite structure of wrought iron may be compared to a fine-meshed screen in which the strands of wire or filaments remaining parallel with the top surface would be from 1-500 to 1-1000-inch apart. Just as these fibres of slag distribute the effect of shock over a larger area of metal, so do they interfere with the progress of corrosion, because, owing to their close formation, the path of corrosion through the metal is retarded and lengthened parallel with its surface, thus greatly increasing the time of penetration.

Slag Not an Accelerator of Corrosion

It has been stated that cinder (slag) acts as "an accelerator of corrosion rather than a protector" because "cinder sets up a galvanic action with the iron and starts active corrosion wherever it is in contact with the iron in the presence of moisture." Based on this assumption, the rate of corrosion of wrought iron should increase in direct proportion to the quantity of slag present, and in view of the 1.5 to 2 per cent of slag, which it actually contains, electrolysis should be expected to destroy wrought iron at a very rapid rate, or at least very much faster than a metal such as steel, which contains no slag at all. Considering for a moment the established reputation of wrought iron in its resistance to corrosion, it is evident that such an assumption does not agree with the facts, and is therefore entirely without merit.

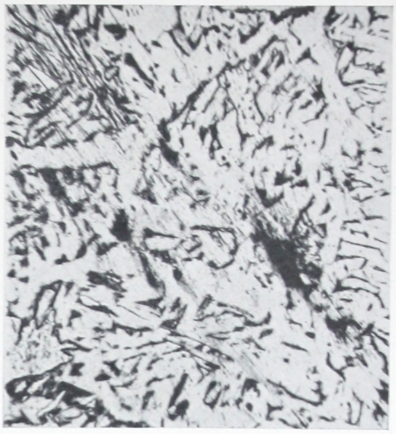
As a matter of fact, slag is virtually a nonconductor of electricity, and consequently any difference of potential would be neutralized while the minute currents caused by electrolytic action upon the surface or other portions of the metal would be reduced and so effect a corresponding decrease in the rate of corrosion.

In view of the above, let us ask the exponents of steel pipe to explain on the basis of their contention that slag acts as an accelerator of corrosion, the reason for the unique and remarkable resistance to corrosion which wrought iron pipe is admitted to possess.

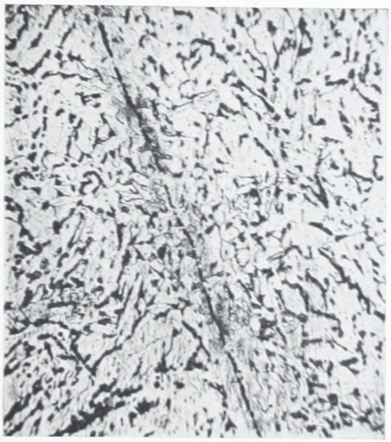
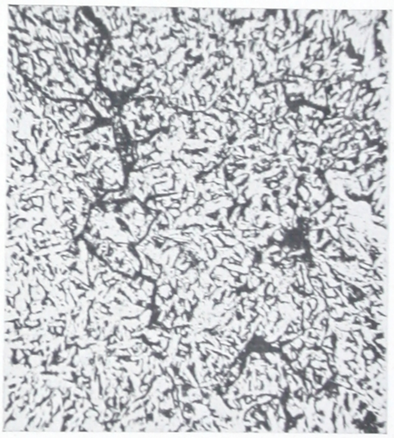
If there were the slightest element of truth in their contention, how can they justify one single instance where wrought iron pipe has proven vastly superior to steel pipe. Yet, there are hundreds of just such cases as evidence of the overwhelming proof of the superiority of wrought iron over steel pipe under identical conditions of service.

Every length of Reading Wrought Iron Pipe has the word READING rolled in the iron as shown on above illustration, except Redrawn Pipe, which has the letters depressed.





Figs. 9, 10 and 11. Photo-micrographs of longitudinal section of steel taken from the same length of special upset rotary drill pipe, showing the varying degrees of segregation in the same length of pipe. Fig. 9 showing least, Fig. 10 showing more, and Fig. 11 showing most. Figures 10 and 11 show sections which will quickly be affected by crystallization, with the resulting danger of having the drill pipe suddenly twist off.

Figs. 12 and 13. Photo-micrographs of steel section magnified 100 diameters through weld showing good lapweld and .07 to .08 carbon. Note the black line is the lapweld.

Fig. 14. Photo-micrograph of steel section magnified 100 diameters from the same length as Figs. 12 and 13, showing a burnt area and also a much higher carbon—.16 to .18.



Figs. 15, 16 and 17. Photo-micrographs of steel section magnified 100 diameters, showing varying degrees in the carbon content ranging from .07 to .13. Fig. 15 being a fair example, Fig. 16 bad, and Fig. 17 very bad.

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